

Serial No. 450,215

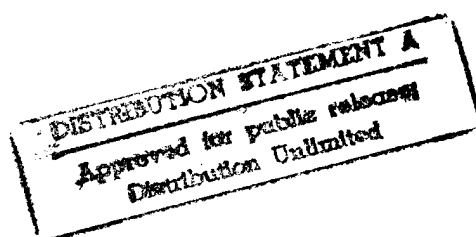
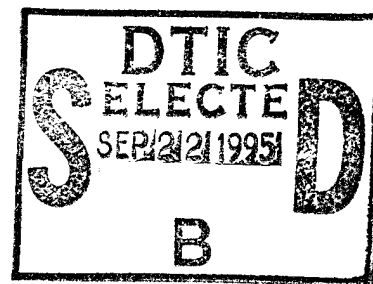
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Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

CONTINUOUSLY WRAPPED FIBER OPTIC TOWED ARRAY

BACKGROUND OF THE INVENTION

Field of the Invention

In general this invention describes a fiber optic towed hydrophone array, more specifically a towed array having a series of hydrophones spaced along the length of the towed array structure.

Description of the Related Art

Previously fiber optic towed arrays have been constructed utilizing Fabry-Perot interrogation techniques utilizing a continuous method of wrapping an optical sensing fiber over a specially constructed array structure, as shown in **Figure 1**. The array structure **10** must be chosen such that extensional waves which may be excited by the towing process are not strongly coupled in to the hydrophone units **12**. Further, the individual section of the continuous structure forming the plurality of hydrophone units **12** must be significantly more acoustically sensitive than the interconnect part of the structure so that the noise picked up by the interconnecting optical fibers **14** does not contaminate the acoustical signal response of the array **10** when

Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

sensed by the reference interferometer 16. Additionally, the array 10 must be flexible enough to be capable of being deployed and retrieved by reeling the array 10 around a drum or similar type retrieval device.

5 Continuously wrapped fiber optic towed arrays have in the past had hydrophones 12 consisting of a single air-backed plastic tube forming the mandrel 18, as shown in Figure 2, and the longitudinal strength member, upon which the sensing optical fiber 14 was wrapped in sections to form each hydrophone. These
10 arrays, because of the longitudinal strength member 18 is a continuous tube which also forms the mandrel for the hydrophone 12, strongly couples noise due to the towing process into the hydrophone response, completely overwhelming any acoustic signals, which may have been present. This array is not
15 decoupled in any way from the hydrodynamic flow during towing.

SUMMARY OF THE INVENTION

20 The object of this invention is to provide a towed array providing an acoustic signal with a minimum of hydrodynamic flow noise.

 Another object of this invention is to provide a fiber optic towed array that lend itself to continuous construction and is less acceleration sensitive.

25 This is achieved by having a towed array comprised of a

Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

series of rigid acoustically sensitive air-backed plastic mandrel
hydrophone devices separated by a distance that allows for the
reeling in or out of the towed array. Each hydrophone unit is
comprised of one or more series of air-backed plastic mandrel
5 devices wrapped with an optical fiber. Once the optical fiber is
wrapped around the mandrels to form the hydrophone device, a cage
structure is applied to each unit and the whole array structure
is wrapped in a thin layer of open cell foam material. The foam
wrapped hydrophone is then placed inside of a hose so as to
10 decouple the hydrodynamic flow noise from the hydrophone during
towing.

BRIEF DESCRIPTION OF THE DRAWINGS

15 **Figure 1** is a schematic of the Fabry-Perot technique for
array interrogation as used in the prior art.

Figure 2 is a schematic of the array structure used in the
prior art.

20

Figure 3 is a schematic of the array structure as set forth
in the present invention.

Figure 4 is a schematic of a mandrel section of the towed
25 array as set forth in the present invention when a reference

Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

fiber is incorporated into the array structure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

5 The continuously wrapped fiber optic towed array 20, as
shown in Figure 3, consists of a series of hydrophone 30 devices
separated by a distance sufficient to allow for reeling of the
complete array 20. The spacing between the hydrophones 30, which
is dependent upon the desired acoustic frequency, is maintained
10 by a strength member 22 passing through the center of each of the
hydrophones 30. The strength member 22 is chosen such that it
does not couple acceleration energy into the array 20, an example
of a strength member 22 would be an aramid rope, manufactured by
Gulf Rope and Cordage of Mobile, AL. Each hydrophone 30 unit
15 consists of one or more optical fiber wrapped air-backed plastic
mandrel devices (not shown). Within the hydrophone 30, the
optical fiber 23 is split by an input coupler (not shown) into a
sensing optical fiber arm, or sensor arm, 23a and a reference
optical fiber arm, or reference arm, 23b. Upon exiting the
20 hydrophone 30, the sensing arm 23a and reference arm 23b are
recombined by an output coupler (not shown) to form the single
optical fiber 23 again. The regions between the hydrophone 30
devices may be strain relieved by an aramid rope strength member
22 to ensure that the finished array 10 may be reeled and towed.

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Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

Referring now to **Figure 4**, the basic component of the hydrophone 30 is a sensing assembly (not shown). Upon entering the hydrophone 30 the optical fiber is split by an input optical coupler 42a to form the sensing arm 23a and reference arm 23b, as previously stated. The sensing arm 23a and reference arm 23b are wrapped onto separate tubular cylindrical air backed plastic mandrels 28 and 32, respectively. The sensing mandrel 28 nominally has an outer diameter of 0.75 inches and an inner diameter of .625 inches. Nominally the reference mandrel 32 has an outside diameter of .5 inches and an inside diameter of .47 inches. However, the outer may vary from one inch to .625 inches. The reference mandrel 32 is located inside the tube formed by the sensing mandrel 28 and the two mandrels 28 and 32 are separated by a spacer collar 38, the construction of which is well known to the art. The spacer collar 38 provides an air spacing between the reference mandrel 32 and sensing mandrel 28 comparable to the range of outer diameters of fibers wrapped on the reference mandrel 32 and the inner diameter of the sensing mandrel 28.

The sensing arm, 23a is comprised of an optical fiber having a nominal diameter of 165 μ m wrapped onto the sensing mandrel 28, the optimal pitch of such windings being 165 μ /turn. The optical fiber comprising the sensing arm 23a may have a length between 40 meters and 200 meters dependent upon the sensitivity required and

Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

it may be any acceptable optical fiber known to the art, such as, an optical fiber part no. CS 1300 manufactured by Corning, Inc. of Corning, NY.

5 The reference arm, 23b is comprised of an optical fiber having a nominal diameter of 165 μ m wrapped onto the reference mandrel 32 the optimal pitch of such windings being 165 μ /turn. The optical fiber comprising the reference arm 23b may have a length approximately equal to the length of the sensing fiber and
10 may be of the same type fiber. By the use of techniques well known to the art, the reference arm 23b may be eliminated, however, a supporting tube may still be required for the housing of couplers 42a and 42b and/or support for the strength member 22.

15 At the output, the sensing arm 23a and reference arm 23b are recombined into the optical fiber 23 by an output coupler 42b. Both the input coupler 42a and output coupler 42b may be located inside of the tubular cylindrical reference mandrel 32. This
20 internal area of the reference mandrel 32 may be potted with an epoxy resin, such as Chockfast Orange [®], made by ITW Philadelphia Resins of Montgomeryville, PA.

25 Once the sensing assembly (not shown) is wrapped with the sensing and reference arm 23a and 23b, respectively, a perforated

Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

cage structure 24 made of brass, anodized aluminum or stainless steel, is applied over each hydrophone 30 unit. The perforations 24a allow the acoustic pressure wave to reach the sensing mandrel 28. A gap of approximately 0.125 inches is formed between the
5 sensing arm 23a and the cage structure 24. Endcaps 44a and 44b, with penetrations to allow the passage of the strength member 22 and optical fiber 23, are attached to the input and output ends of the cage structure 24, respectively. The endcaps 44a and 44b fit into the inner diameter of the cage structure 24. The outer
10 diameter of the cage structure, nominally one inch in diameter, is then wrapped in a thin layer of open cell foam 34, such as that manufactured by Foam Fair Industries of Aldan, PA, approximately .25 inches in thickness or thicker as required to fill the hose 36. The foam 34 wrapping continues along the
15 entire length of the array 10 not only covering the cage structure 24 but also covering, but not necessarily touching, the strength member 22 between hydrophones 30.

The foam 34 covered cage structure 24 is then placed within
20 a hose 36 having a thickness of approximately .25 inches, such as manufactured by Raychem Corp. of Menlo Park, CA. The purpose of the assembly formed by the foam 34 and the hose 36 is to decouple the hydrodynamic flow noise from the hydrophone 30 during towing.

25 With the preferred embodiment of this invention, the overall

Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

strength in the array 10 is continuous forming alternating soft (the area between the hydrophones 30) and rigid (the hydrophones 30) portions which decouple the vibrations due to acceleration. Each individual sensor assembly (not shown) forming the

5 hydrophone 30 is protected from the foam 34 and the wall of the hose 36 by the cage structure 24 -- physical contact from these items can introduce noise in the hydrophone 30 response. The containing of the array 10 within the open cell foam 34 and hose 36 wall attenuates any noise present due to water flowing past
10 the array 10 during towing, thereby improving the signal-to-noise performance.

The precise dimensions of the various components of the hydrophone 30 sections, the foam 34 and the hose 36 may be varied
15 so as to meet any desired system specification. The number of mandrel units which form each individual hydrophone 30 may be varied in response to array 10 aperture requirements. Multiple layers of optical fiber 23 may be wrapped on each mandrel section to enhance the sensitivity of the finished hydrophone 30.

20 Multiple array 10 apertures may be formed by wrapping more than one string of fiber optic gratings/mirror (not shown) on the mandrel sections and varying the number of mandrel sections per hydrophone 30 unit. Array 10 shading may be achieved by varying the pitch of the windings on the array 10 structure.

Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

The preferred embodiment of this invention will accommodate not only the Fabry-Perot technique, but such other schemes as the frequency division multiplexing (FDM) or time division multiplexing (TDM) for Mach-Zehnder and Michelson type
5 interferometers. In the case of the other schemes, the necessary couplers and splices may be potted into the centers of the appropriate mandrel sections. While these interrogation schemes do not lend themselves as easily to the continuous wrap construction procedure, they may have superior optical and
10 acoustic performance.

Obviously, many modifications and variations of the present invention are possible in light of the above teaching. It is therefore to be understood that,

15 the invention may be practiced otherwise than as specifically described.

Inventors: Dandridge et al.
Serial No.:

PATENT APPLICATION
Navy Case No. 75,923

ABSTRACT

A towed array having of a series of rigid acoustically sensitive air-backed plastic mandrel hydrophone devices connected in cascade by a strength member and separated by a distance that
5 allows for the reeling in or out of the towed array. Each hydrophone unit is comprised of one or more series of fiber wrapped tubular cylindrical air-backed plastic mandrel forming a sensing optical fiber arm and a reference fiber arm assembly with the reference fiber arm being located within the sensing fiber
10 arm and separated by an air gap forming a sensing assembly. A cage structure is applied over the sensing assembly leaving an air gap between the sensing fiber arm and the cage forming the hydrophone assembly. The hydrophone assemblies are then wrapped in a thin layer of open cell foam material throughout the array.
15 The foam material and hydrophone structures spaced along the strength member are then placed inside of a hose so as to cover the entire array that acts to decouple the hydrodynamic flow noise from the hydrophone during towing. The overall strength in the array is continuous forming alternating soft (the area
20 between the hydrophones) and rigid (the hydrophones) portions which damp the vibrations due to acceleration. This invention will accommodate not only the Fabry-Perot technique, but such other schemes as frequency division multiplexing (FDM) or time division multiplexing (TDM) for Mach-Zehnder and Michelson type
25 interferometers.

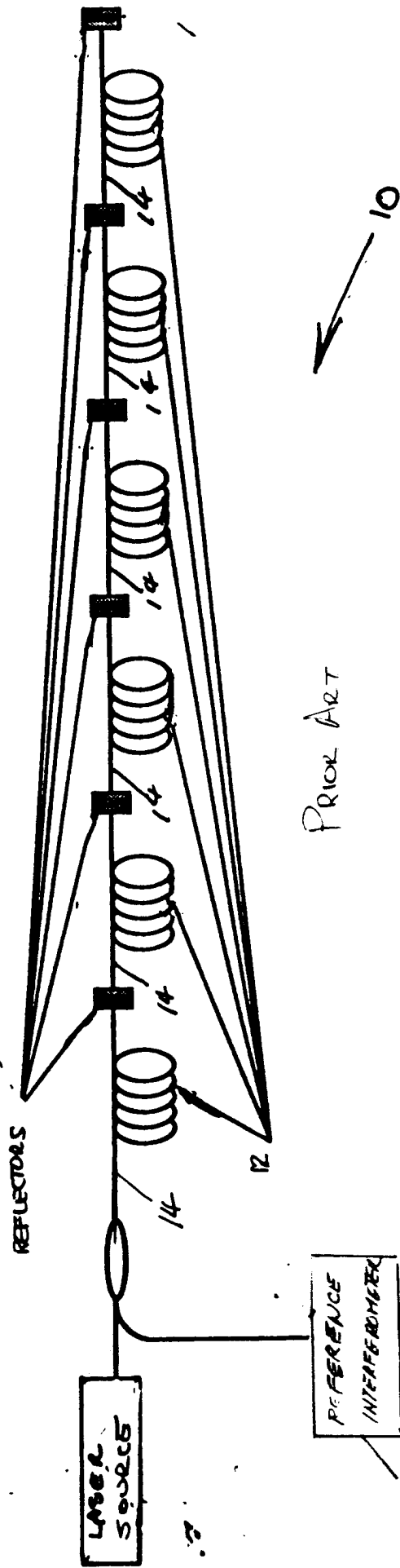


FIG 1

Prior Art

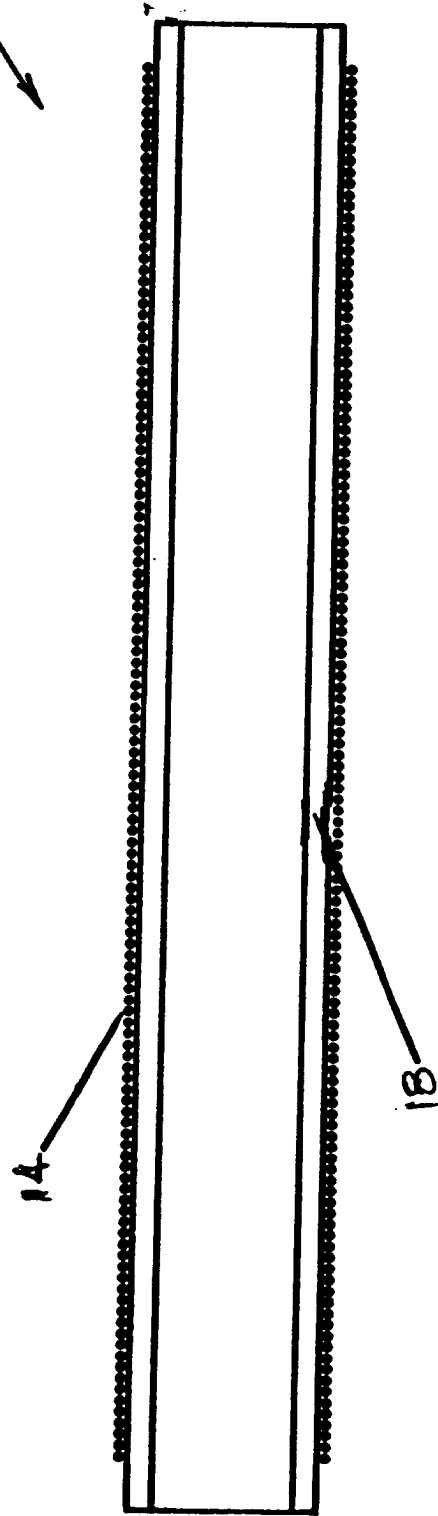


FIG 2

Prior Art

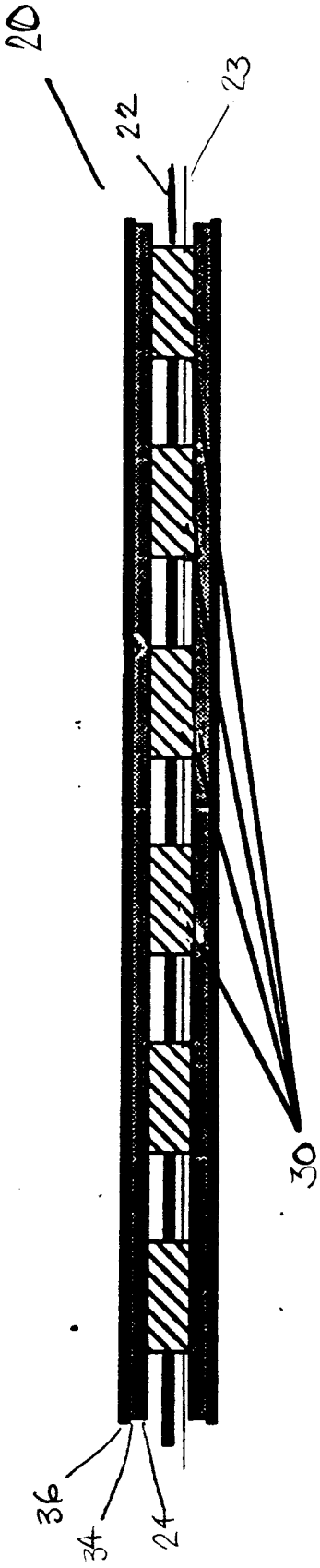


Fig. 3

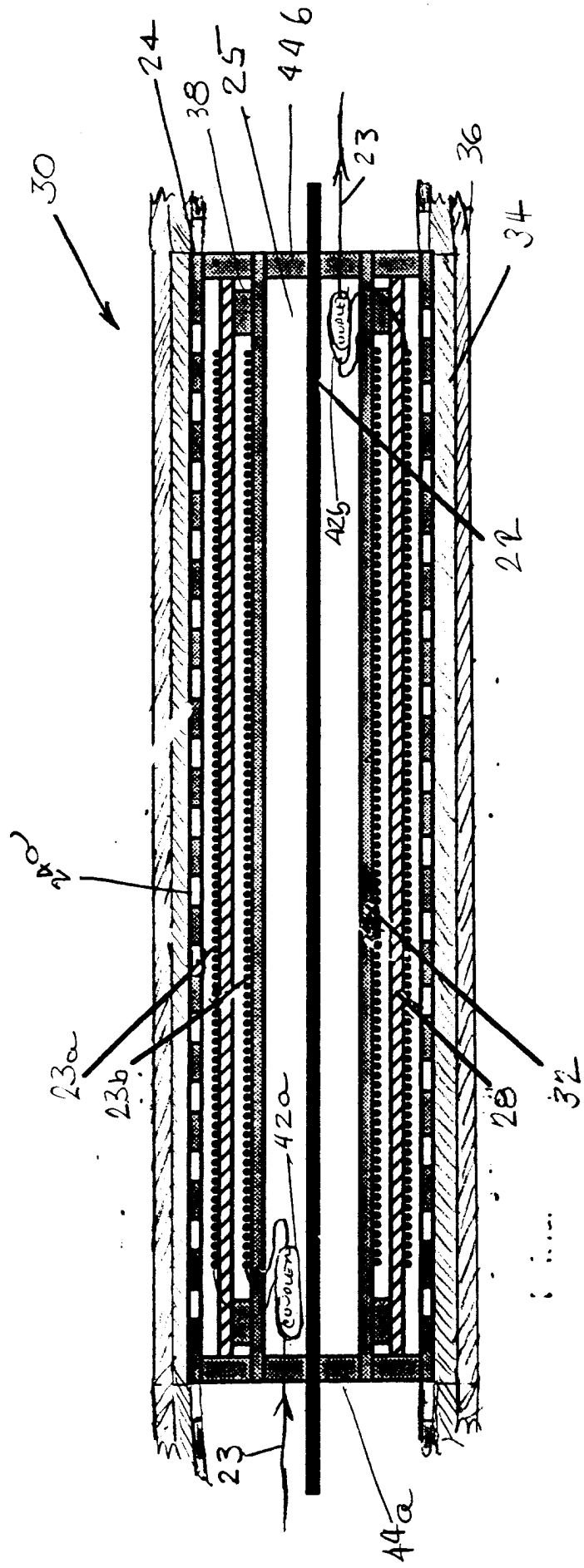


Fig. 4